CNTT-E-148

BASIC ELECTRICITY AND ELECTRONICS

STUDENT HANDOUT

NO. 311

SUMMARIES, PROGRESS CHECKS

FOR MODULES

32-5, 33-1, 33-2, 33-3

JUNE 1984

SUMMARY
LESSON 5

Crystal Controlled Oscillators

In any oscillator circuit, there is a method to select the desired operating output frequency. Crystal controlled oscillators provide extremely stable output frequencies. The property which allows a crystal to oscillate is known as the "piezoelectric effect" and is shown in Figure 1.

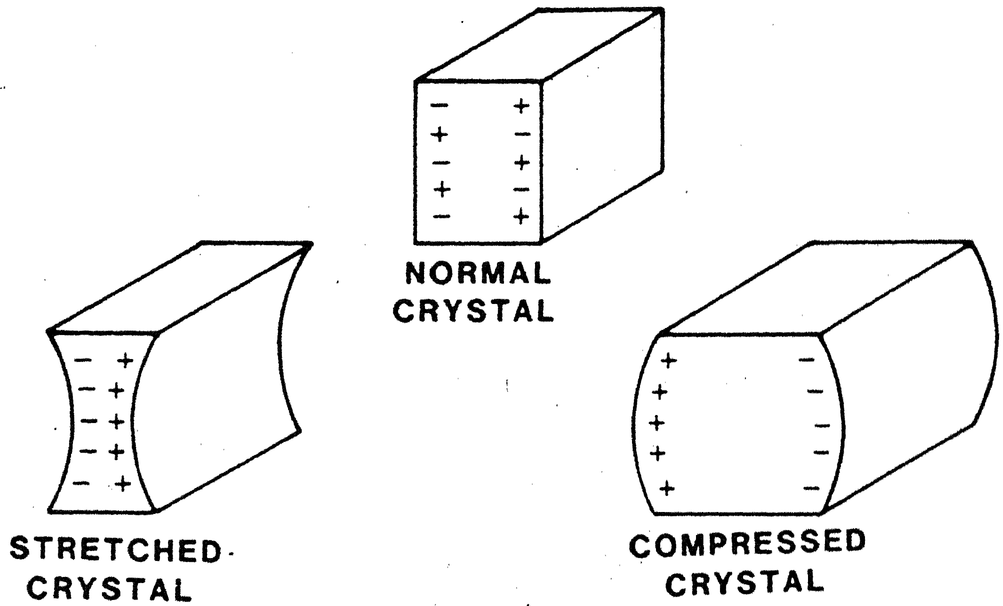

Figure 1

PIEZOELECTRIC EFFECT

As shown in the figure, tourmaline, Rochelle salt and quartz crystals will vibrate at their natural resonant frequencies when a voltage is applied. Conversely, vibrating crystals produce a voltage at a frequency which depends on the thickness of the crystal. The thinner a crystal is cut, the higher is both its natural resonant frequency and the AC voltage frequency it produces.

As in any oscillator, the AC voltage produced by a crystal oscillator will damp out unless regenerative (in-phase) feedback is received by the crystal. The crystal itself acts like an LC tank circuit at the desired frequency with a very narrow bandwidth and very high Q. Figure 2 compares the bandwidths of a crystal and an LC tank.

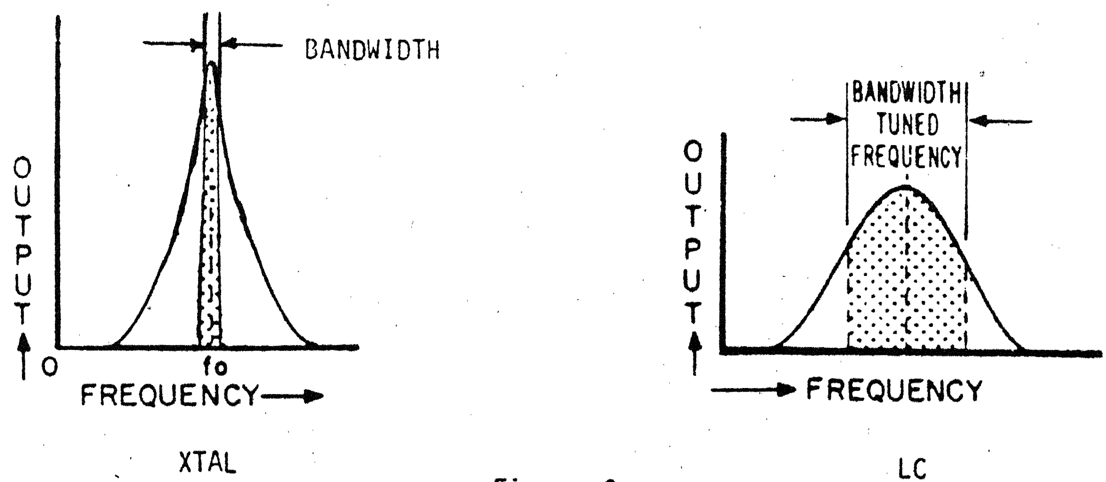

Figure 2

CRYSTAL VS LC TANK BANDWIDTH

Quartz is the most common material used in crystals. The schematic diagram for a crystal is shown in Figure 3.

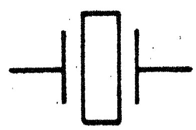

Figure 3

CRYSTAL SYMBOL

Electrically, a piece of unmounted quartz crystal is equivalent at a certain frequency to the series resonant circuit shown in Figure 4.

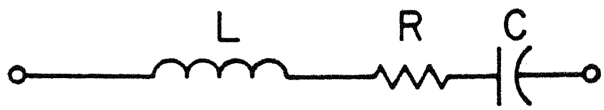

Figure 4

AC ELECTRICAL EQUIVALENT OF QUARTZ

When a crystal is mounted in a metallic holder, the electrodes attached to the crystal appear in parallel with the crystal as shown in Figure 5.

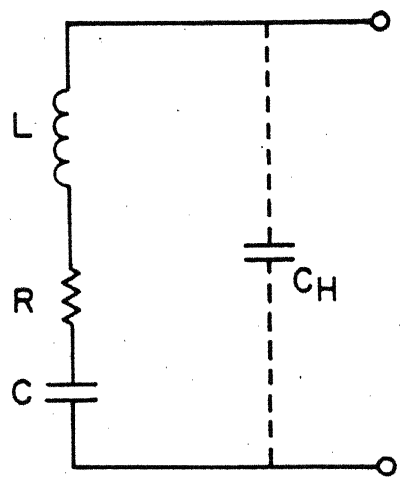

Figure 5

CRYSTAL EQUIVALENT CIRCUIT

A crystal oscillator operates at two distinct frequency points, or "modes". The series resonant mode is the natural resonant frequency of the crystal. The parallel mode (or anti-resonant mode) is caused by the parallel holder capacitance. The parallel mode occurs at a frequency slightly higher than that of the series resonant mode.

The effect of the two modes of operation are shown in the frequency response diagram in Figure 6.

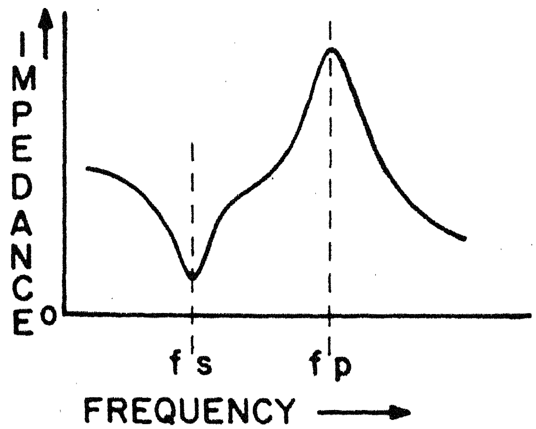

Figure 6

CRYSTAL IMPEDANCE VS FREQUENCY

As the frequency of a voltage applied to a crystal approaches the series resonant frequency (fs), the impedance of the crystal drops to a very low value. As the frequency of the applied voltage approaches the parallel resonant frequency (fp), the impedance increases sharply, thus exhibiting the characteristics of a parallel resonant tank.

In the Wien-bridge oscillator circuit automatic gain control (AGC) is used in order to maintain the output amplitude stability. This is shown in Figure 5.

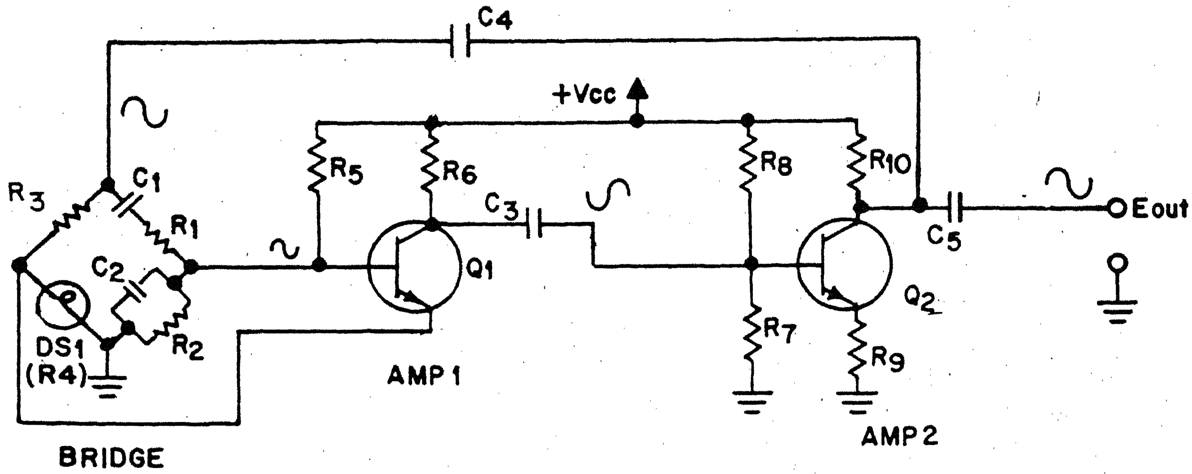

Figure 5

WIEN-BRIDGE OSCILLATOR CIRCUIT WITH AGC

The control is accomplished by substituting a tungsten filament lamp for R_4 in the degenerative voltage divider circuit part of the bridge. This is shown in the schematic. The lamp is designated as DS1. The resistance of the lamp varies as the temperature of its filament increases or decreases. Any increase in the resistance of R_4 (DS1) results in a higher degenerative feedback voltage, whereas any decrease in the resistance results in a smaller degenerative voltage. The tungsten lamp operates much like an AC voltage regulator and maintains a constant output amplitude by varying the amount of degenerative voltage applied to the emitter of transistor Q_1. A thermistor may be used instead of the lamp. This device is also temperature sensitive and functions like the lamp. Thermistors are available with either positive or negative temperature coefficients. The circuit application will determine the type of thermistor which is required. With the Wien-bridge oscillator, a thermistor with a positive temperature coefficient is required.

The tickler coil (Armstrong) crystal oscillator shown in Figure 8 is an example of an oscillator circuit which operates in the series resonant mode.

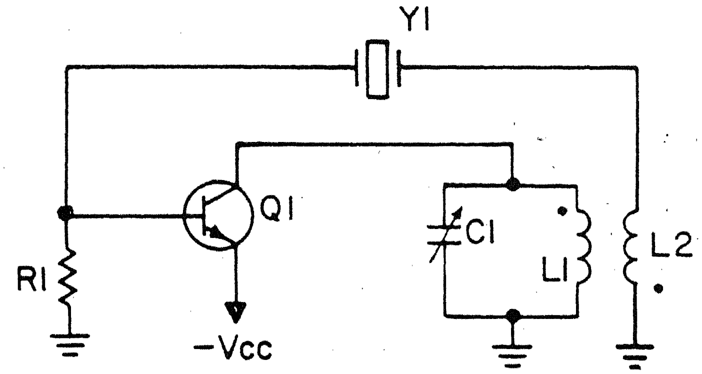

Figure 8

TICKLER COIL CRYSTAL OSCILLATOR

The L1C1 tank acts as the collector load, and is tuned to the crystal's resonant frequency. The crystal operates as a series resonant circuit to a single frequency which it passes to the base of Q1. The crystal filters out all other frequencies thus providing frequency stability.

In crystal oscillators, exact adjustments may need to be made to the crystal due to circuit requirements or crystal aging. Small adjustments to its operating frequency, called "pulling the crystal", can be made by placing a variable capacitor or inductor in series or in parallel with the crystal. A small value trimmer capacitor is often used as shown by component C_4 in Figure 9.

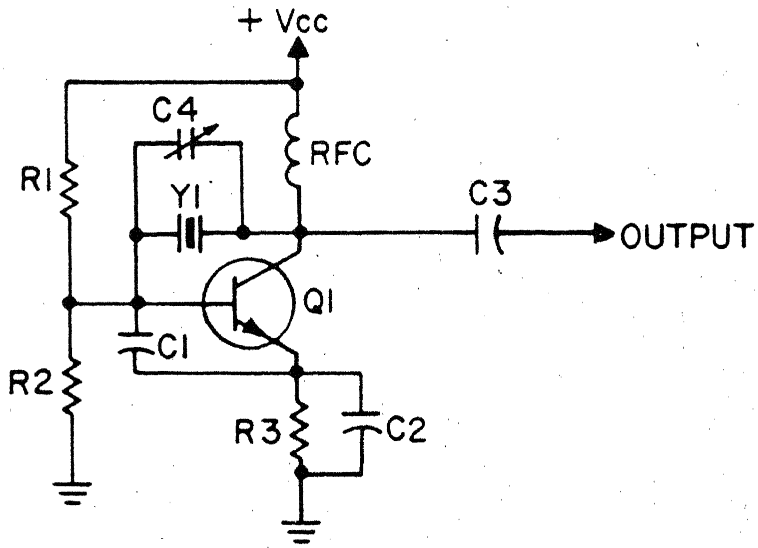

Figure 9

PIERCE CRYSTAL OSCILLATOR WITH TRIMMER

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PROGRESS CHECK
LESSON 5

Crystal Controlled Oscillators

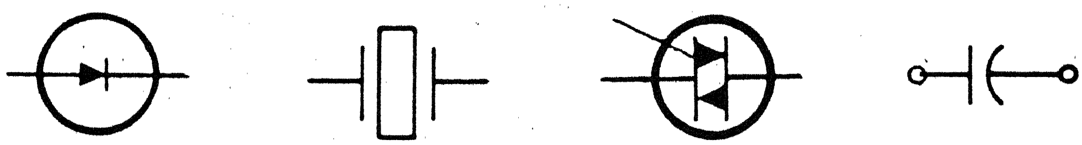
1. A crystal operates because of the piezoelectric effect, which means the crystal

   a. produces high gain amplification of a narrow band of input signals.
   b. produces an undamped AC output voltage when provided a DC input voltage.
   c. converts voltage to pressure distortions, and pressure to voltage.
   d. converts AC input signals to rectified DC, and DC input signals to rectified AC.

2. The frequency of a crystal oscillator is controlled by

   a. an LC tank.
   b. the crystal.
   c. an RC network.
   d. the RFC choke.

3. The schematic symbol for a crystal is



1. 2. 3. 4.

   a. 1
   b. 2
   c. 3
   d. 4

4. A crystal mounted in a holder has the property of

   a. a parallel resonant circuit.
   b. a series resonant circuit.
   c. either 1 or 2.

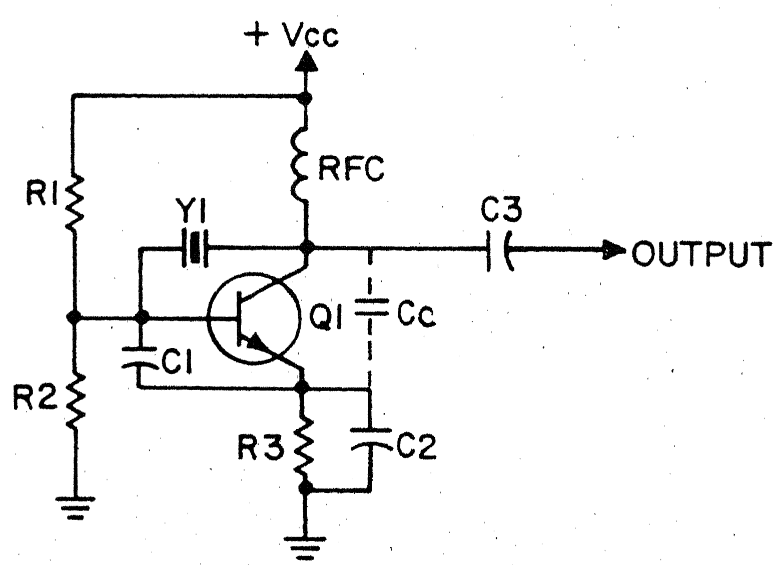
5. In a crystal oscillator, the parallel mode of operation occurs at a ________ which is slightly higher than that of the series resonant mode of operation.

   a. frequency
   b. temperature
   c. stability
   d. Q

6. A crystal operating in the series resonant mode has a characteristic (low/high) impedance, and a crystal operating in the parallel mode has a characteristic (low/high) impedance.

   a. low, high
   b. high, high
   c. low, low
   d. high, low

USE THE FIGURE BELOW OF A CRYSTAL CONTROLLED OSCILLATOR CIRCUIT TO ANSWER QUESTIONS 7 THROUGH 10.



7. The oscillator in the figure is called a ________ crystal oscillator, and operates in the ______________ mode.

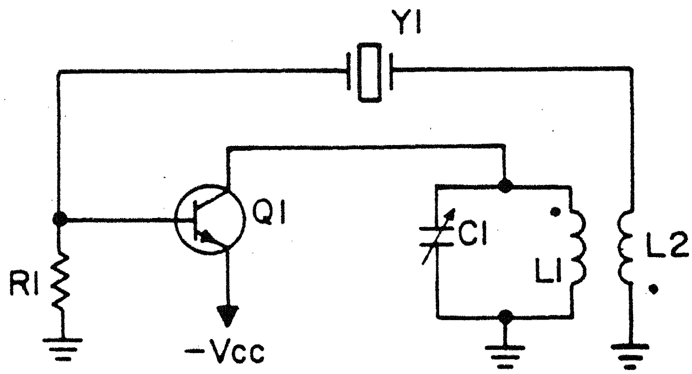
8. The optimum feedback voltage is provided by component __________.

9. A capacitive voltage divider is formed by C1 and ________.

10. When compared to a collector load resistor, the RFC in the circuit has (lower/higher) DC resistance with (lower/higher) AC reactance.

   a. higher, lower
   b. lower, higher
   c. lower, lower
   d. higher, higher

USE THE FIGURE BELOW OF A CRYSTAL CONTROLLED OSCILLATOR CIRCUIT TO ANSWER QUESTION 11.



11. The oscillator in the figure is called a _________ _________ oscillator, and operates in the _________ _________ mode of the crystal.

12. "Pulling the crystal" is performed in order to

   a. eliminate stray reactance.
   b. match oscillator input and output impedance.
   c. make the regenerative feedback in-phase.
   d. make small operating frequency adjustments.

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SUMMARY
LESSON 1

Delay Lines

Many electronic equipments use delay lines to trigger some circuits at later times than others. Most delay lines are divided into two categories: electromechanical and electromagnetic.

Electromechanical delay lines convert electrical input signals into mechanical motion (ultrasonic energy), transfer this energy as motion through some physical medium, and reconvert it to electrical output signals. The time delay depends on the medium used (such as mercury, a steel spring, quartz crystal) and the length of the delay line.

Figure 1 shows the signal characteristics for electromechanical delay lines.

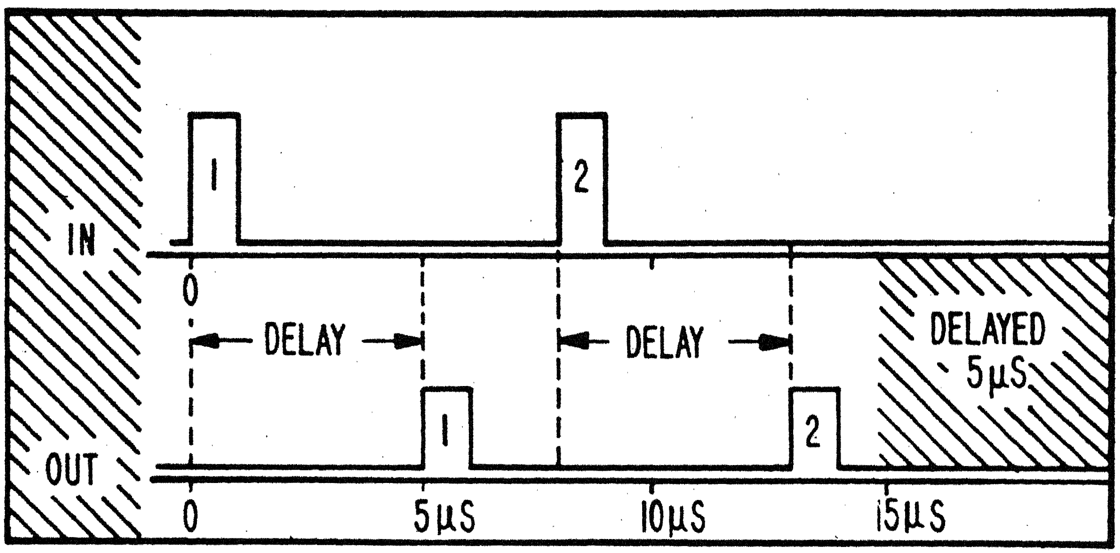

Figure 1

ILLUSTRATION OF ELECTROMECHANICAL TIME DELAY

The output signal is a delayed, non-distorted, and attenuated copy of the input signal.

One type of electromechanical delay line is made up of a column of mercury with a slab of quartz crystal at each end as shown in Figure 2.

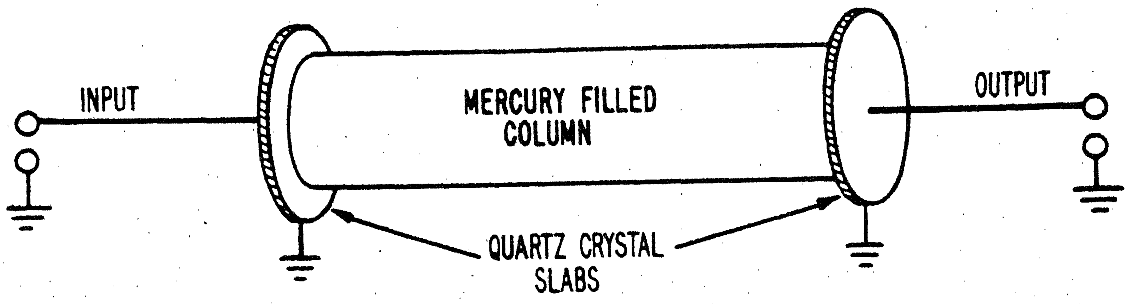

Figure 2

ELECTROMECHANICAL MERCURY DELAY LINE

The mercury delay line uses the piezoelectric effect of the quartz crystals to convert electrical energy into mechanical energy, and reconvert mechanical energy back into electrical energy.

Electromagnetic delay lines are devices which function through the action of charging and discharging capacitance, and expanding and collapsing inductive, or magnetic, fields. Standard coaxial cable (coax), as shown in Figure 3, may be used as a electromagnetic delay line.

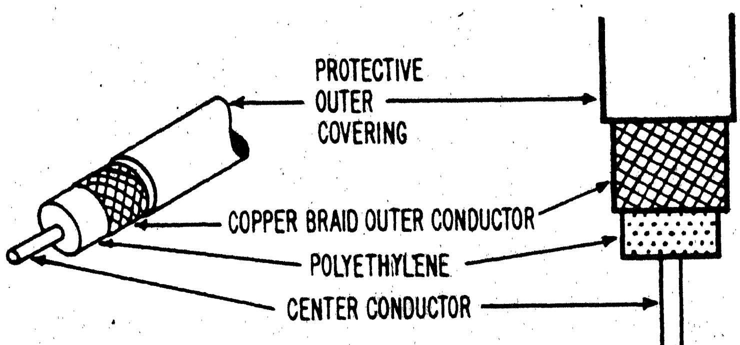

Figure 3

STANDARD COAXIAL CABLE

The time delay in coaxial cable is directly proportional to cable length.

Spiral-wound coaxial cable, as shown in Figure 4, produces a time delay which is about 14 times greater than that of standard coax, because of the coiled center conductor.

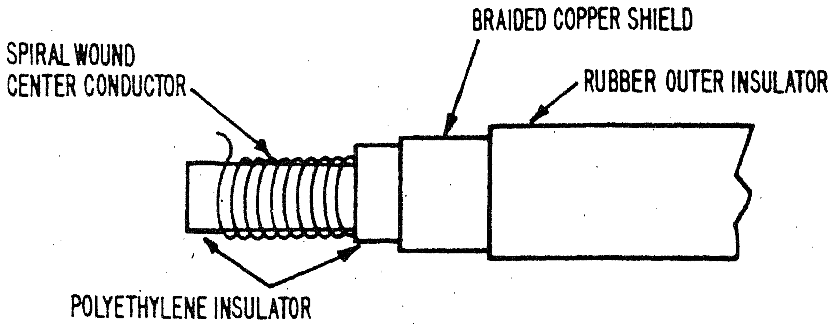

Figure 4

SPIRAL COAX DELAY LINE

Spiral-wound coax is more commonly used because of its space-saving feature.

The lumped constant delay line, as shown in Figure 5, is used to produce very long delays when component size must be minimized. This type of line uses real capacitors and inductors to produce the delay.

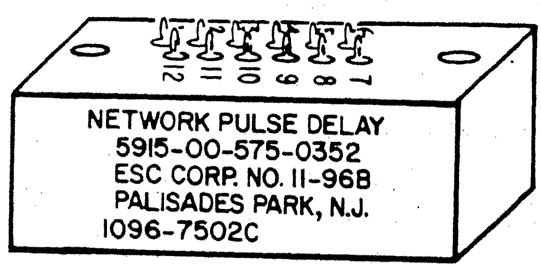

Figure 5

LUMPED CONSTANT DELAY LINE

This type of delay line can be manufactured to provide exact time delays of relatively long duration in a very small package size.

Waveguides must be used as a delay line when the frequency of the input signal reaches the microwave frequency range. A waveguide is a cylindrical or rectangular metal pipe, as shown in Figure 6, commonly used as a microwave frequency transmission line.

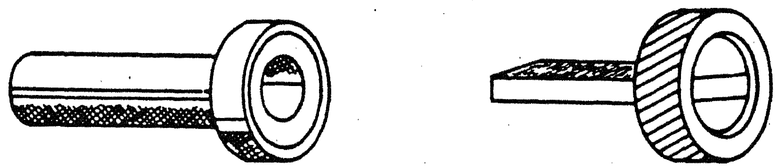

Figure 6

WAVEGUIDES

In electromagnetic delay lines as in electromechanical delay lines, the output signal has the same shape and pulse width as the input signal. Also, the output signal is attenuated. The amount of time delay and signal attenuation is directly proportional to delay line length.

As a rule of thumb, maximum energy transfer and minimum distortion occur in electromagnetic delay lines if the input source and output load impedances are matched to the delay line. An example of impedance matching is shown in Figure 7. Notice that $Z_g = Z_{in}$ and $Z_{out} = Z_L$

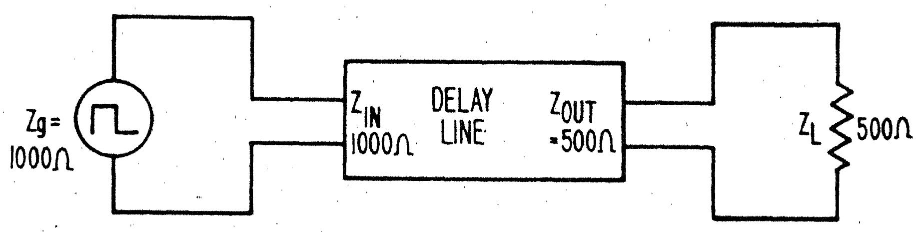

Figure 7

DELAY LINE IMPEDANCE MATCHING

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PROGRESS CHECK
LESSON 1

Delay Lines

1. Delay lines are used in electronic circuits to slow down ________ signals.

2. The general type of delay line which uses the energy of mechanical motion is called __________.

3. A mercury delay line functions by using

   a. capacitance and inductance.
   b. reactance and resistance.
   c. mechanical motion.
   d. electromagnetic waves.

4. Electromagnetic delay lines use actual or apparent __________ and _________ to cause time delay.

   a. inductors, resistors
   b. capacitors, inductors
   c. capacitors, resistors
   d. resistors, diodes

5. Four meters of standard coaxial cable produce a .04 microsecond time delay. Therefore, _________ meters of the same cable would produce a .08 microsecond time delay.

   a. 2
   b. 6
   c. 8
   d. 16

6. In electromagnetic delay lines, the input and output signals have (<u>the same</u>/<u>different</u>) shapes.

7. Attenuation in delay lines means that the output signals have ___________ ___________ when compared to the input signals.

   a. lower frequencies
   b. different shapes
   c. higher frequencies
   d. smaller amplitudes

8. The ________ __________ delay line, per unit length, produces a longer time delay than the ________ _________ delay line.

   a. standard coax, lumped constant
   b. standard coax, spiral-wound coax
   c. spiral-wound coax, standard coax
   d. spiral-wound coax, lumped constant

9. Waveguides are used as delay lines at microwave frequencies to

   a. replace mercury delay lines.
   b. replace lumped constant and coax delay lines.
   c. match input and output pulse widths and waveforms.
   d. provide longer time delays using less space.

10. An input source to an electromagentic delay line has an impedance of 2000 ohms. The output load has an impedance of 1000 ohms. Maximum energy transfer will occur if the delay line input impedance is _________ ohms, and output impedance is _________ ohms.

   a. 2000, 1000
   b. 2000, 2000
   c. 1000, 1000
   d. 1000, 500

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SUMMARY
LESSON 2

Dummy Loads

Many times you will find it necessary to test electronic equipments, such as power supplies and transmitters, without connecting them to their normal load devices. In these situations, dummy loads are used. A dummy load is a device that appears to any equipment under operation to be the normal load.

Figure 1 shows two common examples where electrical dummy loads can be used.

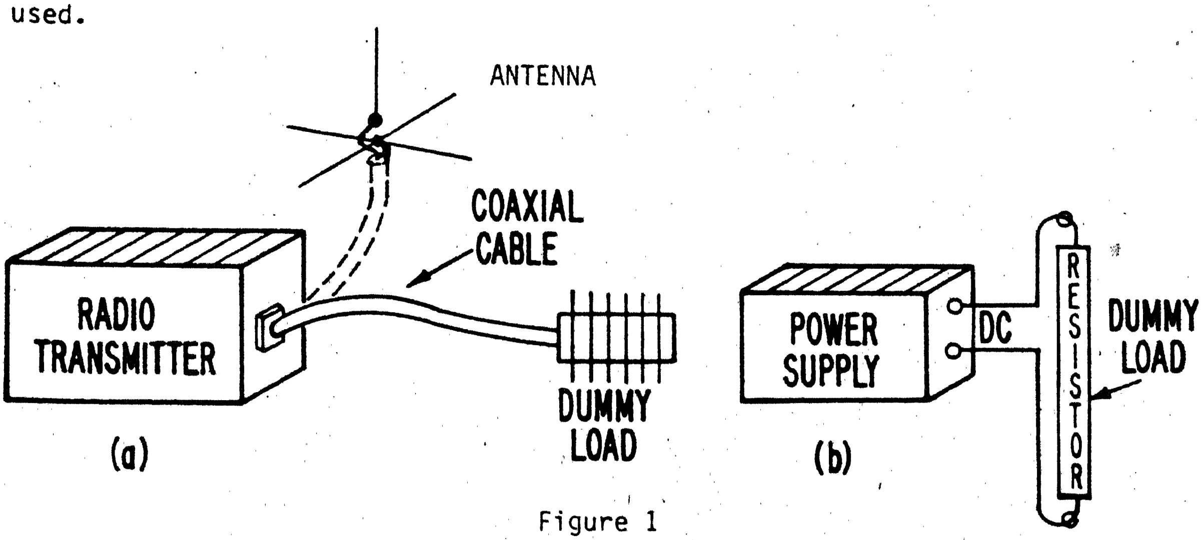


Figure 1

DUMMY LOAD APPLICATIONS

When using dummy loads, the normal loads are isolated electrically from the circuits. The dummy loads allow you to operate and troubleshoot the radio transmitter and power supply without the problems related to using the normal loads. Dummy loads can replace the normal loads of circuits as well as of complete equipments.

A resistive dummy load converts the output energy from an operating equipment into heat. Two requirements for using all resistive dummy loads are:

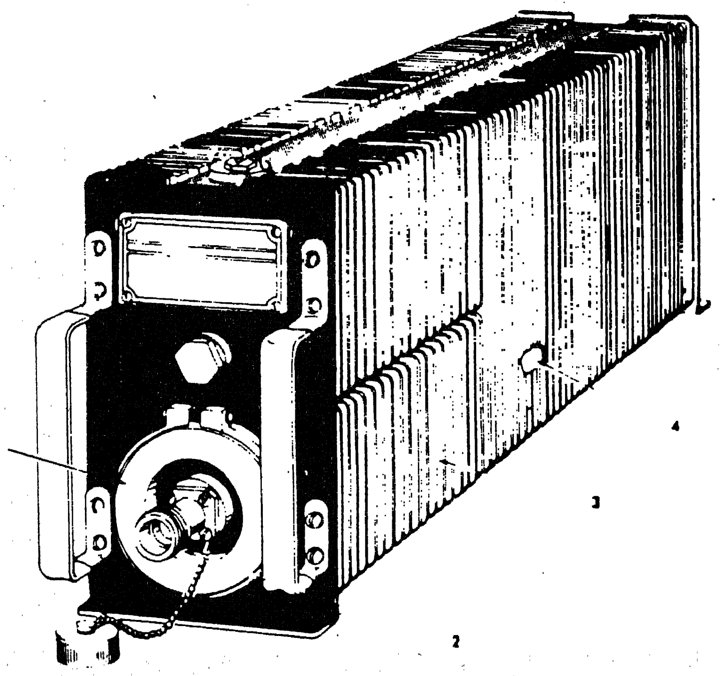
1. The dummy load resistance must be as close as possible to the actual value of load resistance (R_L).

2. The dummy load power rating must be high enough to dissipate the power produced by the equipment or circuit.

A resistive dummy load can be a fixed resistor or a rheostat. Fixed resistors of proper values and power ratings are commonly used as dummy loads for AC or DC power supplies over a wide range of power outputs.

A resistive dummy load which replaces the antenna of a radio transmitter must be capable of dissipating a large amount of heat caused by the RF energy. Two types of dummy load used for this purpose are coaxial and waveguide dummy loads. In both types, the resistive element is made of a special mixture containing powdered graphite with an adhesive compound. This mixture is formed into a tapered cone, and placed into a heat sink to dissipate the heat into the air.

Coaxial dummy loads are used at frequencies in the RF communications range. A coaxial cable transmission line connects the radio transmitter to the dummy load. In this case the fixed output impedance of the transmitter (usually 50 ohms resistive) is matched by a 50 ohm coax cable and 50 ohm dummy load. Figure 2 shows an exterior view of a coaxial dummy load.



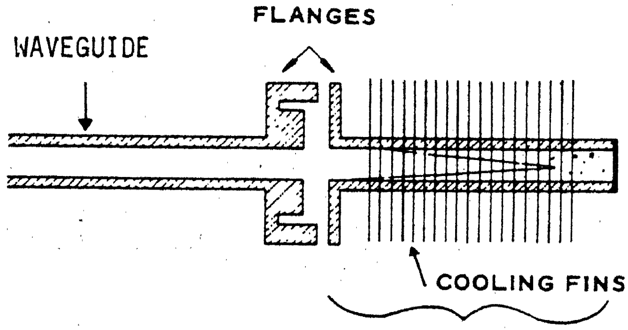
1. Resistive element
2. RF input connector
3. Metal cooling fins
4. Resistive element extending down through cooling fins

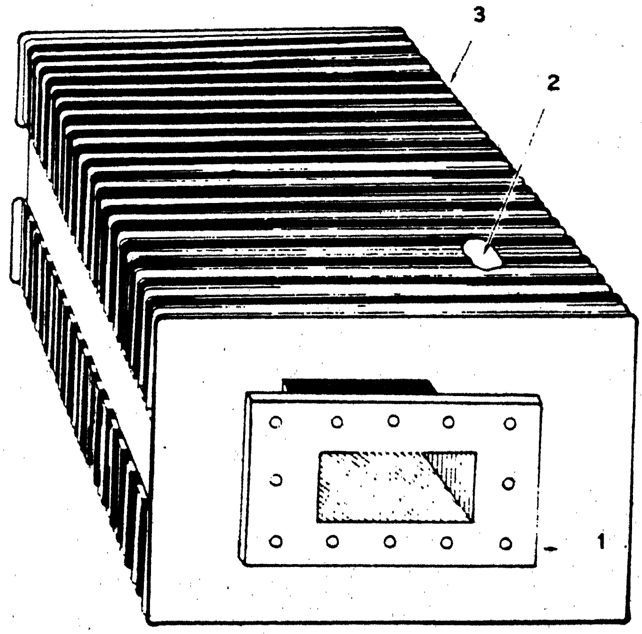
Figure 2

COAXIAL DUMMY LOAD (EXTERIOR VIEW)

Waveguide dummy loads normally are used at microwave (radar) frequencies. A waveguide transmission line connects the radio transmitter to the dummy load. The resistive element is contained within a piece of waveguide.

Figure 3 illustrates a waveguide dummy load.





1. Flange used to bolt waveguide dummy load to waveguide.
2. Waveguide extends through cooling fins.
3. Cooling fins.

Figure 3

WAVEGUIDE DUMMY LOAD

In both coaxial and waveguide dummy loads, some RF energy is not dissipated as heat and leaks into the surrounding space. When radio silence is required, the Commanding Officer must give permission to transmit even into a dummy load.

The previous discussion has dealt with electrical dummy loads. One other category of dummy load is the mechanical dummy load which is a device that simulates mechanical loads.

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PROGRESS CHECK
LESSON 2

Dummy Loads

1. A dummy load is used in the testing of an electronic equipment to

   a. reduce the output power of the equipment under test.
   b. replace the normal load on the equipment under test.
   c. reduce the output load resistance of the normal load.
   d. increase the impedance of the normal load.

2. A resistance dummy load converts its output energy into _______ energy

   a. heat
   b. light
   c. acoustical
   d. electrical

3. The component you would use as a dummy load on a power supply is a

   a. coil.
   b. capacitor.
   c. diode.
   d. resistor.

4. The output load of a power supply is 200 volts and 4 amperes. A dummy load on this power supply must have a resistance equal to __________ ohms.

5. A normal load for a power supply requires 300 volts and 3 amperes. A dummy load on the same power supply must have a minimum power rating of ______________ watts.

6. A coaxial dummy load normally would be used in place of a(n) (RF antenna/power supply load).

7. A waveguide dummy load is used at (radio communication/microwave) frequencies.

8. A radio transmitter output is 1000 watts at 50 ohms impedance. A dummy load on the same transmitter must have a power rating of at least __________ watts.

9. Dummy loads on radio transmitters (will/will not) leak RF energy into space.

10. A lead weight used to test the lifting capability of a fork lift is an example of a(n)____________dummy load.

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SUMMARY
LESSON 3

Special Solid State Devices

The electronic revolution is producing a continuous series of new special devices. Many of these, although originally created to solve a specific problem, are finding seemingly endless applications. Among the more important new devices are those in the optoelectronic group (LEDs, photodiodes, etc.), the varactor diode, and the triac.

Optoelectronic devices either produce or use light in their operation. Their schematics typically show two arrows pointing either away from the basic symbol (if light is produced) or in toward it (if light is used). The first of these, the Light Emitting Diode (LED) is shown with its schematic in Figure 1.

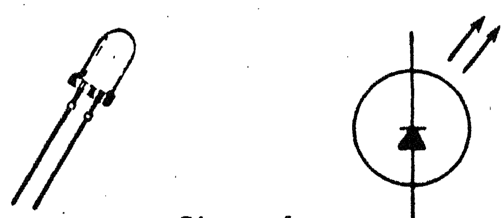


Figure 1

LED

The LED is a diode which, when forward biased, produces visible light. Their extremely small size, low operating voltage and long life make LEDs ideal replacements for incandescent bulbs used as panel indicators and in displays in pocket calculators and the like. Typically, they are used in seven-segment displays like that shown in Figure 2.

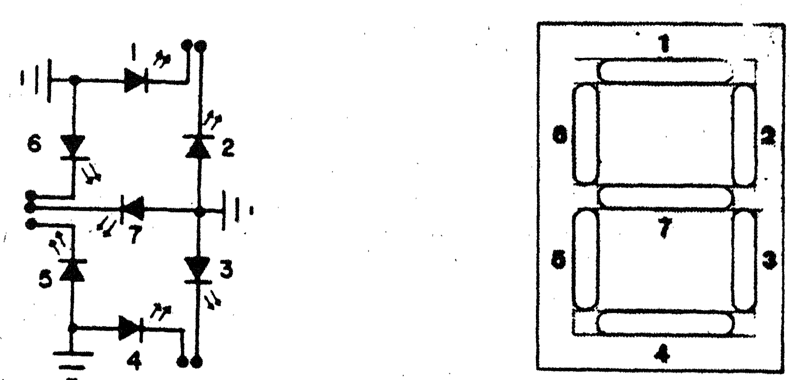


Figure 2

SEVEN SEGMENT LED DISPLAY

This display uses seven LED segments (or bars) which can be lit in different combinations to form any number from "0" through "9". Each segment draws about 10 mA of current when lit. Displays are of the common-anode type, as shown, or the common-cathode type. Often several displays are packaged together in a stack, as for 7- or 9-digit calculators.

A second optoelectronic device, one that uses rather than produces light, is the photodiode, shown with schematic in Figure 3.

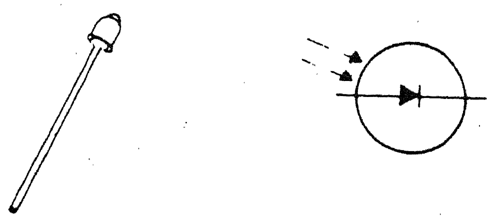


Figure 3

PHOTODIODE

The photodiode is a light-controlled variable resistor. A transparent "window" placed over the semi-conductor chip allows light to reach the diode. The photodiode is reverse biased and conducts current in direct proportion to the intensity of the light source. Photodiodes are used in computer card readers, photographic light meters, and some types of optical scanning equipment.

Another light-using optoelectronic device, the phototransistor, is even more sensitive to light and capable of higher output current than the photodiode. Four types of phototransistors are shown, with schematics, in Figure 4.

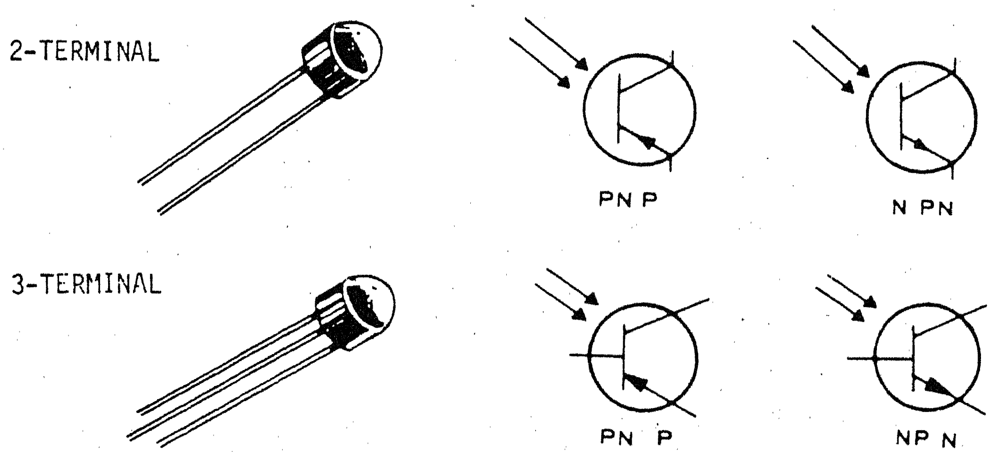


Figure 4

2-TERMINAL AND 3-TERMINAL PHOTOTRANSISTOR

The two-terminal NPN type, as an example, consists simply of a photodiode effectively placed in the transistor base circuit. Light intensity determines the base current. In the three-terminal type, an additional lead is used to apply an electrical bias to the base which can alter the effect of light intensity on transistor conductivity (compensate for ambient light levels, etc.).

An older, similar device is the photoconductive cell, or photo cell, shown with its schematic in Figure 5.

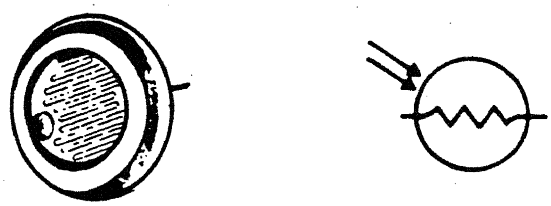


Figure 5

PHOTO CELL

The photo cell is a light-controlled variable resistor with a high light-to-dark ratio--typically 1:1000 or more. Photo cells are used in various timing and control circuits, such as automatic streetlight controllers.

Figure 6 shows the photovoltaic cell, or solar cell, with schematic.

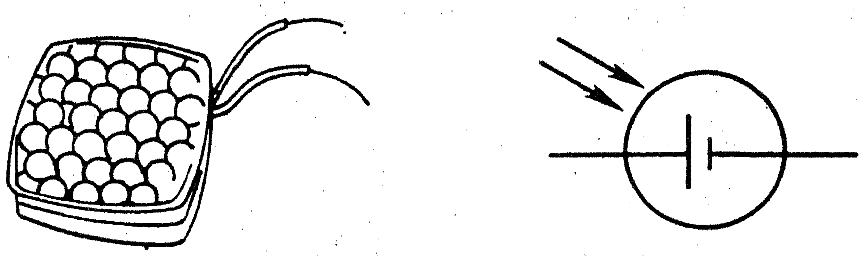


Figure 6

SOLAR CELL

When exposed to light, the solar cell produces about .45 volts and a current in proportion to its size. Connected in series or parallel like batteries, solar cells can produce higher voltages and currents. They are widely used in communications satellites and solar-powered homes.

The optical coupler, shown in Figure 7, combines two optoelectronic devices to achieve total electrical isolation of circuits.

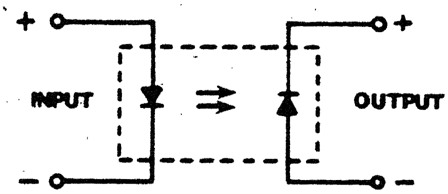


Figure 7

OPTICAL COUPLER

The coupler consists of a forward-biased LED and a reverse-biased photodiode encapsulated so that changes in the input signals are transmitted by light to the output. Couplers like this are suitable for frequencies in the low megahertz range. Where more output is required, couplers combining a phototransistor with an SCR can be used. Optical scanners are replacing transformers in low voltage and current applications, such as digital control circuits.

The varactor diode, the first of two non-optical devices to be covered, is shown with its schematic in Figure 8.

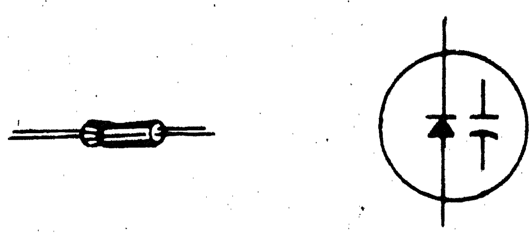


Figure 8

VARACTOR DIODE - PICTORIAL AND SCHEMATIC

The varactor, or varicap, is a diode made to function like a variable capacitor. This is possible due to the effect of reverse biasing on the size of the depletion region surrounding a diode's PN junction, which is illustrated in Figure 9.

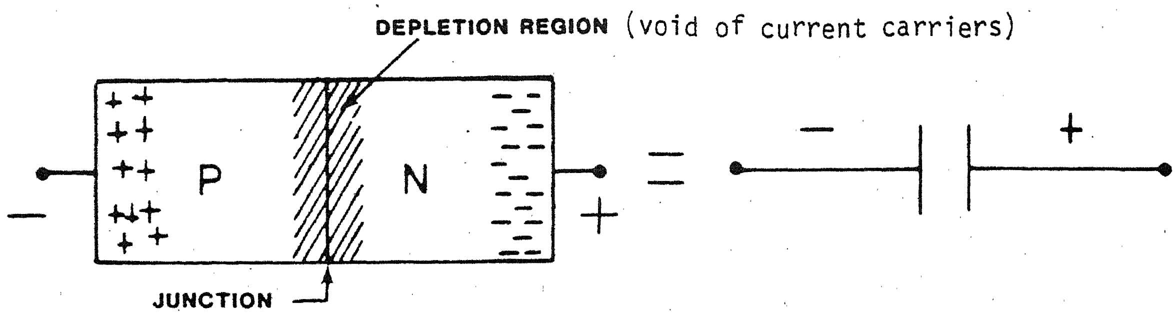


Figure 9

PN JUNCTION VS. CAPACITANCE

Increasing the reverse bias voltage causes the depletion region to widen into an insulating gap comparable to the dielectric in a capacitor. Applying the formula $C = \frac{A\,K}{d}$ (where A = plate area, K = a constant value, and d = distance between plates), it is found that the varactor's capacitance (C) is <u>inversely proportional</u> to applied reverse bias.

Varactors have replaced variable capacitors in many circuit applications, especially sophisticated tuning circuits. One advantage of the varactor is that it allows a DC voltage to be used to tune a circuit with a potentiometer as shown in Figure 10.

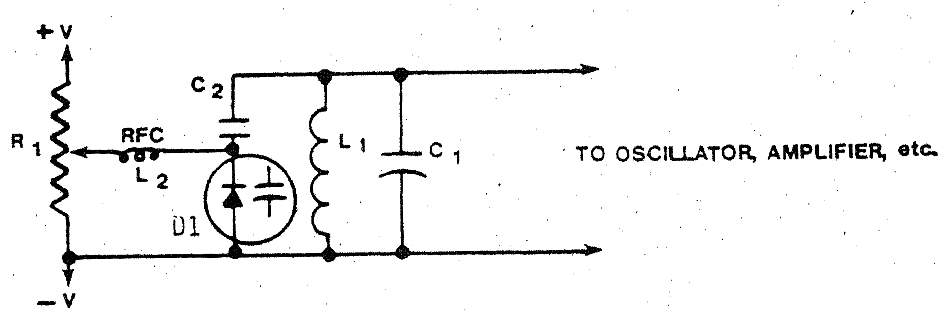


Figure 10

VARACTOR TUNED TANK

The variable DC voltage felt at R1 acts to reverse bias varactor diode D1. Because D1 is in series with C2 and the equivalent capacitance of C2 and D1 is in parallel with tank circuit L1-C1, any variation in the DC voltage at R1 will vary both the capacitance of D1 and the resonant frequency of the tank circuit.

The triac, the last special device to be covered, is a three-terminal device similar to an SCR, as Figure 11 shows.

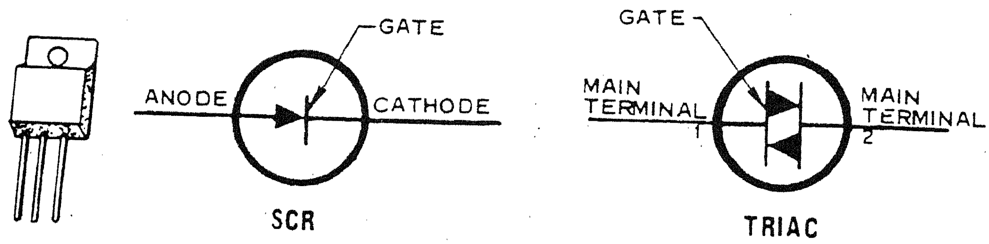


Figure 11

TRIAC VS SCR SCHEMATIC SYMBOLS

The triac is essentially two SCRs back to back, sharing a common gate. It controls current flow during both alternations of an AC cycle, instead of only one as the SCR does, and conducts in both directions. The triac is widely used in circuits which control light intensity and motor speed. A comparison of the waveforms seen at the input, gate, and output of the SCR and the triac is shown in Figure 12.

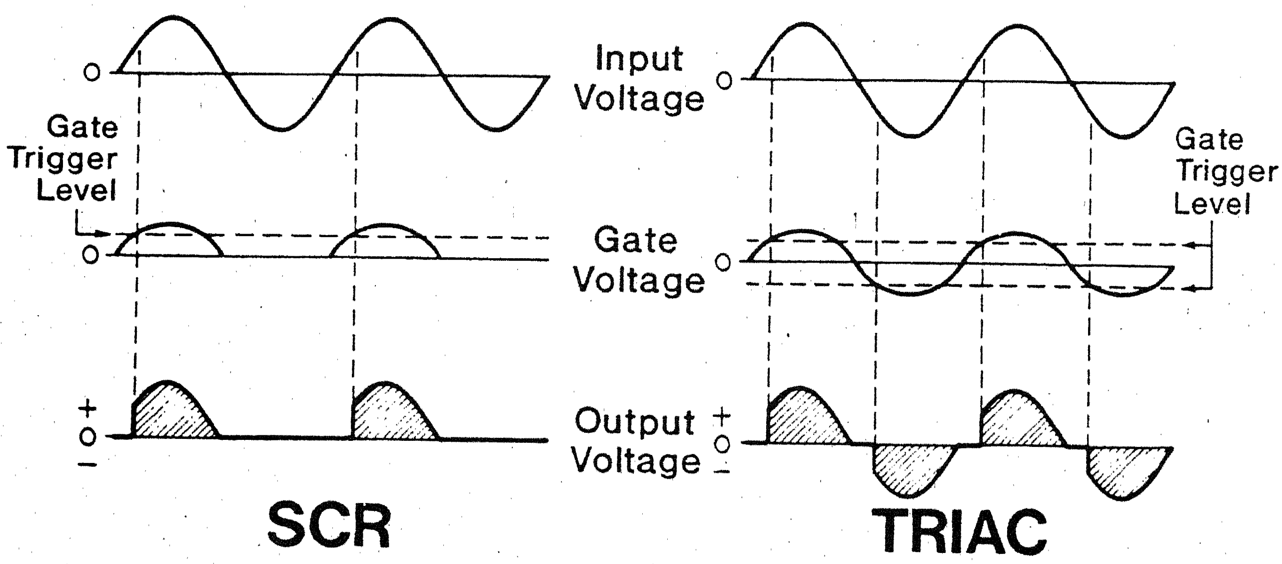


Figure 12

SCR VS TRIAC WAVEFORMS

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRESS CHECK
LESSON 3

Special Solid State Devices

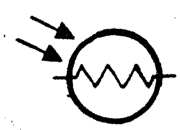
1. The LED, or light emitting diode, (uses/produces) light when it is (forward/reverse) biased.

2. The photodiode (produces light/conducts when exposed to light) and it is (forward/reverse) biased.

3. In a three-terminal phototransistor, conduction is controlled by

   a. light intensity and length of exposure to light.
   b. applied electrical bias and electrostatic fields.
   c. electrostatic fields and length of exposure to light.
   d. applied electrical bias and light intensity.

4. The schematic symbol below represents a



   a. photodiode.
   b. phototransistor.
   c. photocell.
   d. photovoltaic (solar) cell.

5. Which of the following devices is NOT a light-controlled variable resistor?

   a. Photodiode
   b. Phototransistor
   c. Photocell
   d. Photovoltaic (solar) cell.

6. The photocell is most similar in operation to a(n)

   a. photovoltaic cell.
   b. photodiode.
   c. LED.
   d. triac.

7. The photovoltaic cell produces _(light/voltage/heat)_ when _(voltate is applied to it/light shines on it)_.

8. The simplest type of optical coupler combines what two optoelectronic devices?

   a. An LED and a photodiode.
   b. A photodiode and a solar cell.
   c. An LED and a phototransistor.
   d. A phototransistor and a photodiode.

9. When the reverse bias on a varactor diode INCREASES, this causes the size of its depletion region to _(increase/decrease)_ and its capacitance to _(increase / decrease)_.

10. The triac controls current

    a. during the positive alternation of an AC cycle only.
    b. during the negative alternation of an AC cycle only.
    c. during both alternations of an AC cycle.
    d. in DC circuits only.

CHECK YOUR RESPONSES TO THIS PROGRESS CHECK WITH THE ANSWER SHEET. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL OR MOST OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULT WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

ANSWER SHEET FOR

PROGRESS CHECK

LESSON 5

Crystal Controlled Oscillators

QUESTION No.	CORRECT ANSWER	QUESTION No.	CORRECT ANSWER
1.	c.	7.	Pierce, parallel
2.	b.	8.	C1
3.	b.	9.	Cc
4.	c.	10.	b.
5.	frequency	11.	tickler coil, series resonant
6.	a.	12.	d.

ANSWER SHEET FOR

PROGRESS CHECK

LESSON 1

Delay Lines

QUESTION No.	CORRECT ANSWER	QUESTION No.	CORRECT ANSWER
1.	electrical	6.	the same
2.	electromechanical	7.	d. smaller amplitudes
3.	c. mechanical motion	8.	c. spiral-wound coax, standard coax
4.	b. capacitors, inductors	9.	b. replace lumped constant and coax delay lines
5.	c. 8	10.	a. 2000, 1000

ANSWER SHEET FOR

PROGRESS CHECK

LESSON 2

Dummy Loads

QUESTION No.	CORRECT ANSWER	QUESTION No.	CORRECT ANSWER
1.	b. Replace the normal load on the equipment under test	6.	RF antenna
2.	a. heat	7.	microwave
3.	d. resistor	8.	1000
4.	50	9.	will
5.	900	10.	mechanical

ANSWER SHEET FOR

PROGRESS CHECK

LESSON 3

Special Solid State Devices

QUESTION No.	CORRECT ANSWER	QUESTION No.	CORRECT ANSWER
1.	produces, forward	6.	b.
2.	conducts when exposed to light, reverse	7.	voltage, light shines on it
3.	d.	8.	a.
4.	c.	9.	increase, decrease
5.	d.	10.	c.

NOTES

NOTES